The Bow River Water Quality Monitoring 1970 - 1980

Alberta

ENVIRONMENT
Environmental Protection Services
Pollution Control Division
Water Quality Control Branch

86-06278/

THE BOW RIVER WATER QUALITY MONITORING

1970 - 1980

Prepared by:

H.R. Hamilton, M.Sc.

L.J. North, P.Eng.

Alberta Environment

Environmental Protection Services

Pollution Control Division

Water Quality Control Branch

Edmonton, Alberta

April 1986

EXECUTIVE SUMMARY

This report reviews the Bow River water quality data collected during the 1970's and is supplemented by more recent monitoring for selected key variables. Average and maximum observed values are reported for sites spaced along the river from upstream of Canmore to near the confluence with the Oldman River (Ronalane Bridge). Analysis includes comparison of the results to water quality objectives and definition of spatial trends in quality. Industrial, treated sewage, and urban runoff discharges to the Bow River are identified and compared.

The Bow River is a hard-water river in which calcium bicarbonate is the major dissolved salt. A marginal increase in total salt concentration occurred with distance downstream, and was caused by the addition of sodium and sulfate from natural erosion and point-source discharges. Topographic transition and land use changes also resulted in higher average suspended solid concentrations in lower river reaches. Suspended solid levels underwent substantial seasonal variation that was related to river discharge.

During the early 1970's, phenolic concentrations in the Bow River exceeded the Alberta Surface Water Quality Objectives (A.S.W.Q.O., Alberta Environment 1977). However, during the late 1970's, levels were reduced substantially.

Only nine of 22 metals routinely measured in the Bow River were ever measured above the limits of analytical detection. Iron and manganese increased in the lower reaches of the Bow River to levels which exceeded the A.S.W.Q.O. These concentrations can be ascribed primarily to natural erosion and groundwater input. Aluminum increased appreciably downstream of Calgary. The likely source was aluminum hydroxide floc discharged by City of Calgary water treatment plants. Lead, copper, cadmium, chromium, nickel and zinc were rarely observed above detection levels. However, low-level metal concentrations in suspended solids and aquatic plants was reported by Ongley and Blachford (1982) immediately below both Calgary and the Bassano reservoir.

During the 1970's five of a possible 23 organic compounds were detected in the Bow River, all at very low concentrations. Two of the five, alpha-BHC and tne herbicide 2,4-D, showed an increasing trend with distance downstream. As with metals, Ongley and Blachford (1982) also reported that some organochlorine compounds not detected in water samples were present in the suspended particulates and aquatic biota in trace amounts.

In the latter half of the 1970's filamentous algae and aquatic weeds whose growth was related directly to instream nutrient concentrations, became a problem in the lower Bow River. The two major plant nutrients, phosphorus and nitrogen, were found consistently

at low concentrations upstream of Calgary, whereas immediately downstream average levels exceeded the A.S.W.Q.O. Further downstream, concentrations varied considerably between sites as well as seasonally because of biological processing and dilution. The detailed relationship between nutrient loadings, and aquatic weed and algal growth, was addressed by the South Saskatchewan River Basin Limnological Study (Charlton, Hamilton, and Cross 1986; Cross, Hamilton and Charlton 1986).

Bow River bacteriological indicator levels complied with all surface water quality objectives, except in the reach below Calgary, where high fecal coliform counts were observed in the mixing zone downstream of Calgary's sewage treatment plant outfalls. During the summer low flow period, microbial levels in the river gradually declined between Carseland and Cluny to those found upstream of Calgary.

Oxygen levels throughout the Bow River remained generally near saturation for most of the year. However, during years with substantial summer aquatic weed growth, diurnal oxygen fluctuated widely.

There are 18 point source discharges to the Bow River Basin downstream of Banff National Park - nine industrial and nine municipal sewage. Other significant discharges to the river included urban runoff from Calgary and irrigation return flow to the lower reaches.

During 1980 proportional discharges of industrial, municipal and urban runoff to the Bow River Basin were 33%, 60% and 7%, respectively. Within the basin, 87% of the industrial and 97% of the treated sewage input occurred at Calgary. Fertilizer plant discharges were the main industrial input. Petroleum industry inputs included one oil refinery at Calgary and two gas processing plants upstream of Calgary.

Loadings to the river from the two Calgary sewage treatment plants were greater than comparable loadings from industrial and urban runoff sources for most constituents. These included nutrients, biochemical oxygen demand, total salts, phenols, chromium, copper and zinc. Urban runoff, although extremely variable between years, was the major source of suspended solids.

In conclusion, Bow River water quality upstream of Calgary was generally maintained near natural levels. In the lower Bow River, water quality was altered for certain constituents, in particular those related to the input of treated sewage from Calgary. Industrial and urban runoff inputs were generally of minor significance.

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ACKNOWLEDGEMENTS

The authors are grateful to the City of Calgary, Sewers Division, in particular B. McIntosh and J. Sealy, for providing stormwater discharge information and water quality data.

T. Reynoldson, J. Kostler, J. Milos and P. Cross of Alberta Environment, Pollution Control Division, provided valuable technical input and reviewed the draft.

Yvette Duchesneau and Lilliane Godin typed the manuscript.

1.0 INTRODUCTION

The Bow River is one of four major rivers draining the Alberta portion of the South Saskatchewan River Basin. Bow River water is used extensively for domestic, industrial, irrigation and recreation (primarily boating and fishing) purposes along its entire length from Banff National Park to its confluence with the Oldman River. In addition, the river receives treated municipal and industrial wastes. These discharges, along with diffuse inputs such as agricultural and urban runoff, have the potential to alter the water quality and affect the different uses of the river.

The objective of this report is to review the water quality of the Bow River over the period 1970 to 1980. Particular attention is paid to comparison of observed water quality with surface water quality objectives and to definition of changes in quality with distance downstream. Where possible, known inputs from industrial, treated sewage and urban runoff sources are described and compared.

General water quality monitoring of the Bow River has been conducted since the 1950's, while monitoring for many complex variables such as metals and biocides was initiated in the early 1970's. The last report produced by the Water Quality Control Branch (W.Q.C.B.), Pollution Control Division, on the Bow River water quality was in 1972 (Ullman. 1972). A compilation of raw data, collected from 1973 to 1975, was published later without interpretation of trends (Alberta Environment. 1975).

This report addresses primarily the quality of the mainstem Bow River; detailed review of the major tributaries such as the Highwood, Sheep and Elbow rivers is not included. Reference to these tributaries and discharge from them is made only when pertinent to interpretation of trends observed in the Bow River itself.

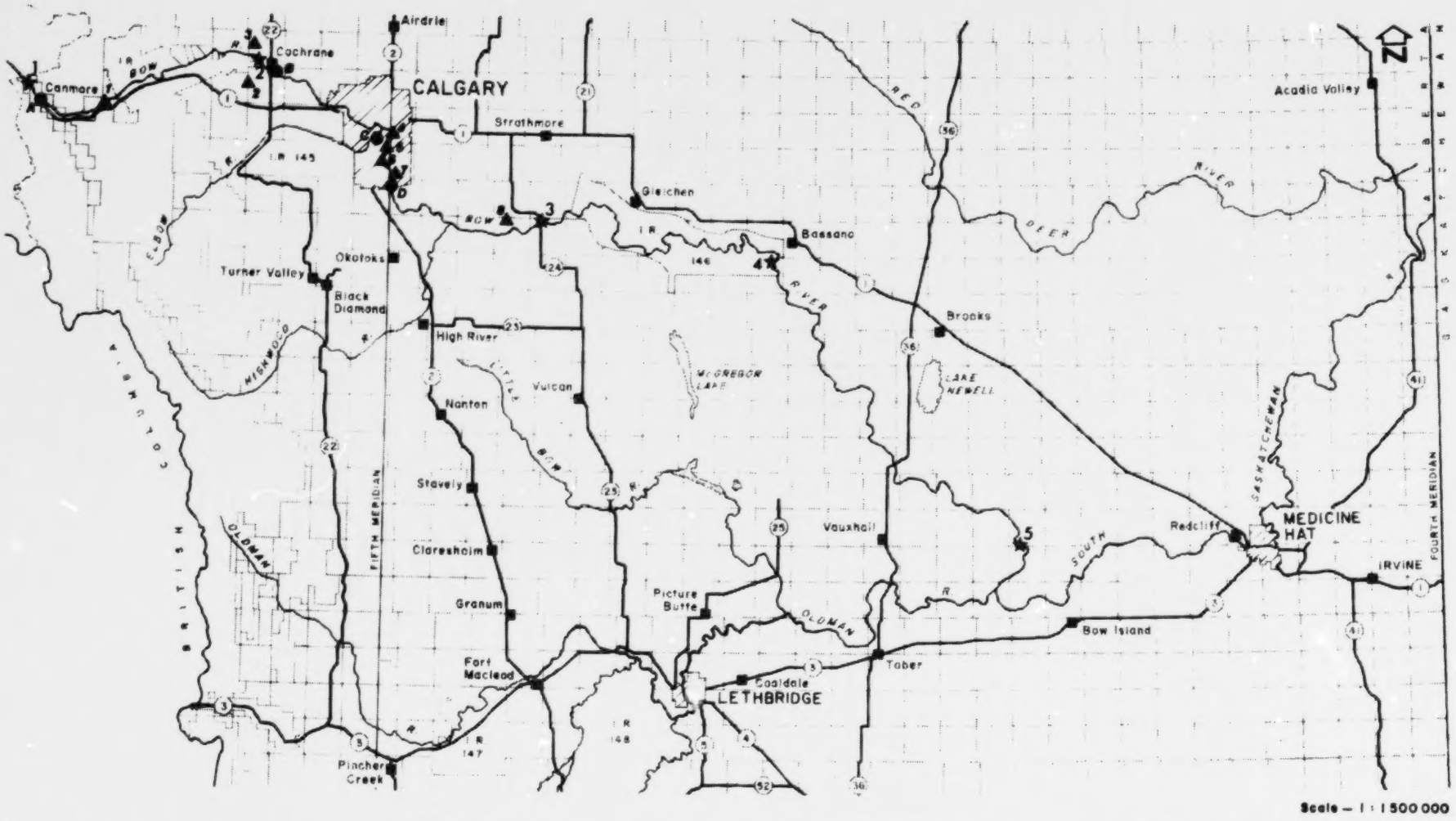
2.0 METHODS

2.1 RIVER WATER QUALITY

Definition of instream water quality for most variables, except nutrients and bacteriological indicators, relied on routine river monitoring data collected by Alberta Environment (W.Q.C.B.) and Environment Canada (Inland Waters Directorate, under contract to Alberta Environment). Detailed data are stored on the NAQUADAT water quality data storage and retrieval system, and this information may be obtained upon request. Nutrient data were derived from the South Saskatchewan River Basin Limnological Study (SSRBLS), a special study on nuisance aquatic weed growth initiated by Alberta Environment in 1979.

Water quality of the Bow River has been monitored at numerous locations along the river for various periods of time. Data from five sites spaced from above Canmore to the Ronalane Bridge are presented in Figure 1. These sites show changes in quality above and below major inputs, and also have a related database. Quality of the river within the national parks reviewed by Block and Gummer (1976-1979) is not discussed here.

Data have been summarized separately for the periods 1970 to 1975, and 1976 to 1980. This was necessary because of variation in monitoring practices and to identify major changes in quality over the decade. All five locations were sampled for most of the first five-year interval. However, since 1975, the routine river monitoring program



★ RIVER SAMPLING SITES

1 Above Canmore
2 Cochrane
3 Carseland
4 Bassano
5 Ronalane Bridge (near confluence)

● SEWAGE TREATMENT EFFLUENTS

A Canmore
B Cochrane
C Calgary (Bonnybrook)
D Calgary (Fish Creek)

▲ INDUSTRIAL EFFLUENTS

1 Canada Cement LaFarge
2 Shell Canada - Jumping Pound
3 Alberta Natural Gas
4 Gulf Canada
5 Burnco Rock Products
6 Cominco (Calgary)
7 Western Co-op
8 Cominco (Carseland)

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FIG. 1. BOW RIVER SAMPLING SITES AND EFFLUENT LOCATIONS

was reduced to include only the sites above Canmore, at Cochrane and at the Ronalane Bridge. Data for each variable are presented as average and maximum recorded values over each five-year interval. Seasonal and discharge variation of river quality are not usually discussed, since there are either minimal dispersion of the results or insufficient sample size.

2.2 EFFLUENT QUALITY AND NET LOADINGS

Industrial effluent quality was summarized from industrial monitoring data collected by Alberta Environment (W.Q.C.B.) from 1976 to 1980. Background concentrations for each variable were estimated from samples collected upstream of Calgary. Net effluent concentrations for each industrial source in Calgary and immediately downstream were calculated by subtracting estimated background river concentrations from average effluent quality. These values, generated for each pertinent variable, were then multiplied by the total effluent discharge for all industries in 1980 to determine the net loading to the Bow River.

Effluent quality of the two Calgary sewage treatment plants (Bonnybrook and Fish Creek) was derived from City of Calgary, Sewers Division (City of Calgary 1980) and Alberta Environment (Municipal Engineering Branch, Pollution Control Division) monitoring data (1979, 1980). Net loadings to the river from Bonnybrook and Fish Creek plants were calculated in the same manner as were industrial inputs.

Calgary urban runoff quality was estimated primarily from data collected for the Nose Creek Water Quality Study (Schonekess 1980). Flow-weighted average concentrations were calculated for most major variables, using data obtained from discharge-related sampling of an urban catchment area draining to Nose Creek. Data were combined from six storms spaced over the summer of 1980. Where necessary, these data were supplemented with results from W.Q.C.B. monitoring of the urban discharge to the Forest Lawn stormwater retention pond (east Calgary), and data from City of Calgary, Sewers Division.

Total Calgary urban runoff to the Bow River for 1980 was calculated by the City of Calgary, Sewers Division. Monthly surface runoff coefficients, derived for the Nose Creek watershed, were applied to 1980 rainfall records and the total Calgary urban area draining to the Bow River, to produce the estimate of annual discharge. The 1980 urban runoff loading to the river represents the product of the total discharge (17,250,000 m^3) and average concentration of the pertinent variables.

3.0 STREAMFLOW REGIME

The Bow River drains an area of 25,000 square kilometres. It originates in glacier-fed lakes north of Lake Louise, then flows south-eastward through the Rocky Mountain Foothills, the Western Alberta Plains and the Eastern Alberta Plains, to its confluence with the Oldman River between Lethbridge and Medicine Hat. Most tributary flow to the Bow River occurs upstream of Calgary, with the Kananaskis, Ghost and Spray rivers giving major inputs. Other major tributaries include the Elbow and Highwood rivers which enter the Bow River at Calgary and downstream of Calgary, respectively. Irrigation return flows, which flow in summer months only, provide the only significant input downstream of the Highwood River. Major diversions of water from the Bow for irrigation occur at Calgary (Western Irrigation District), Carseland (Bow River Irrigation District) and Bassano (Eastern Irrigation District).

Bow River peak discharge occurs in June (Figure 2), and the lowest discharge occurs during late fall and winter. Winter flows are maintained consistently near 50 $m^3 \cdot s^{-1}$ by upstream regulation, whereas June peak and summer discharges vary considerably between years. During the 1970's a number of years with particularly attenuated spring peaks and low summer flows were encountered, notably 1975, 1977 and 1979.

Bow River discharge has a direct effect on water quality by diluting contaminant inputs. Since industrial and municipal effluent flow rates remain relatively constant, river flow volume determines,

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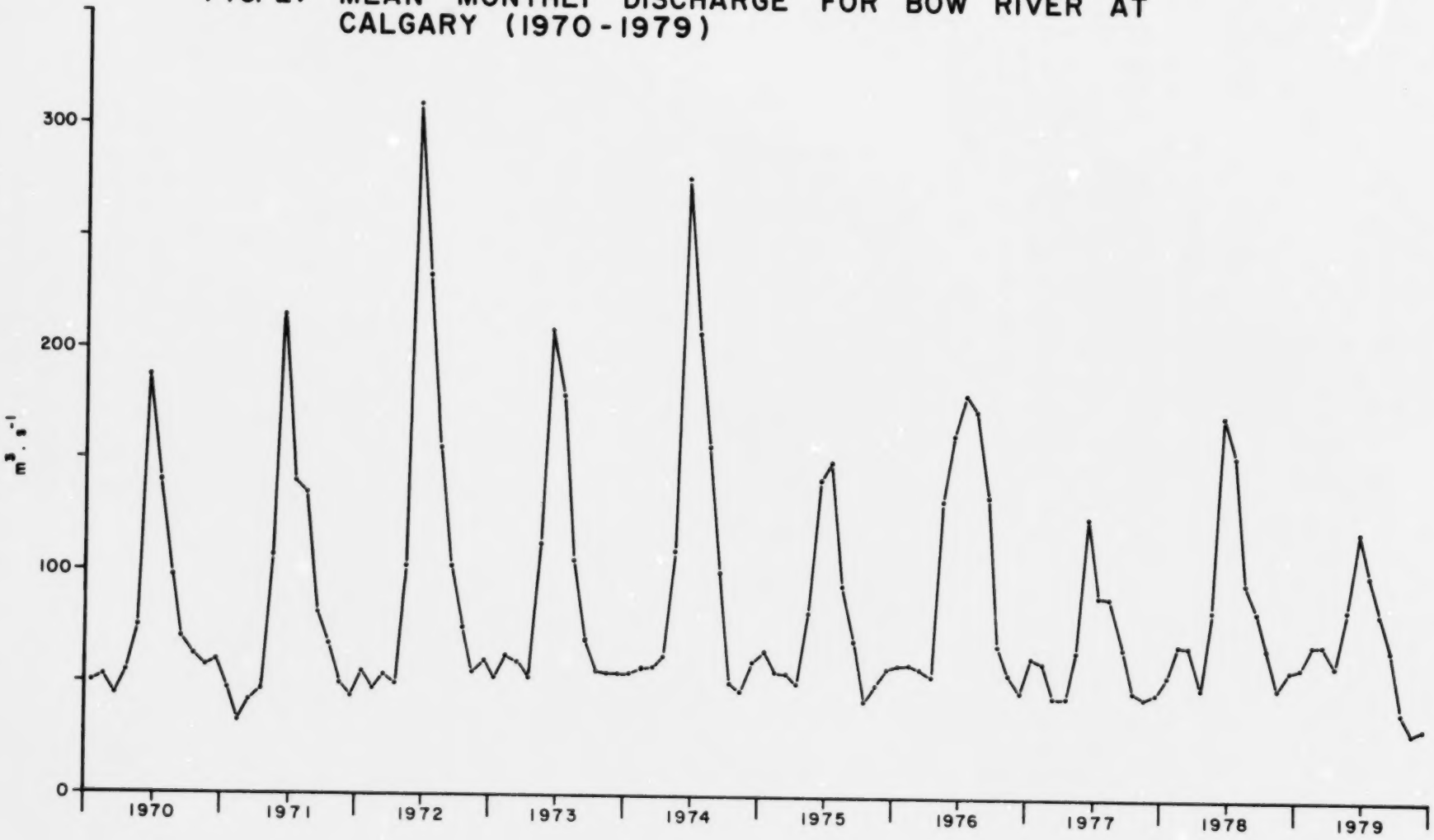
FIG. 2. MEAN MONTHLY DISCHARGE FOR BOW RIVER AT CALGARY (1970 - 1979)



for the most part, the after-mixing river concentration of a specific variable. In the Bow River, the greatest dilution occurs at peak flow in June, and the least dilution occurs in winter months. Consequently, the critical period for wasteload assimilation is late summer, fall and winter. It is during this period that the probability of poor water quality will cause limited use of the Bow River.

Most data are presented as long term average and maximum values. The influence of stream discharge, other physical variables, and biological factors on the most acute Bow River water quality problems have been investigated and are documented in the SSRBLS reports (Charlton et al. 1986; Cross et al. 1986).

4.0 BOW RIVER WATER QUALITY

Average water quality of the Bow River for the periods 1970 to 1975, and 1976 to 1980 is documented. The sampling sites are spaced sequentially along the Bow River from near Banff National Park to the Ronalane Bridge (Figure 1). Data are presented and discussed by subgrouping of related variables or variables which vary in a similar fashion. The corresponding Alberta Surface Water Quality Objective is indicated for each variable.

4.1 ROUTINE VARIABLES

This grouping includes the major inorganic ions, variables related to suspended particulates, and some organic constituents such as biochemical oxygen demand (BOD) and phenolic substances (Table 1).

Since the bedrock of the Bow River Basin is of a limestone-shale complex, the river has high alkalinity and pH. Surface water throughout the basin is classified as hard to very hard, as indicated by total hardness concentrations at times exceeding 180 $mg \cdot L^{-1}$ (McNeely *et al.* 1979).

The main dissolved salt in the river is calcium bicarbonate, with sodium sulfate being of secondary importance. Total salt concentrations, as measured by specific conductance and total dissolved solids, increased with downstream direction, primarily due to increasing levels of sodium, sulfate and chloride. Elevated salt content along the Bow River course is caused partially by natural mechanisms such as physiographic and land use transitions. These transitions include groundwater contributions, decreased forest cover,

TABLE 1 Bow River Water Quality Data Summary (Routine Variables).

	pH						Total Alkalinity ($mg \cdot L^{-1}$)						Phenolphthalein Alkalinity ($mg \cdot L^{-1}$)					
	1970-75			1976-80			1970-75			1976-80			1970-75			1976-80		
	n	Low	High	n	Low	High	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	40	7.7	8.6	33	7.9	8.5	26	111	126	6	108	124	26	0	0	22	0	3
Cochrane	71	7.8	9.0	41	7.9	8.6	69	118	148	21	123	152	64	L1	5	35	6.3	168
Carseland	102	7.1	9.4	-	-	-	98	129	189	-	-	-	75	1	26	-	-	-
Bassano	29	7.7	9.7	-	-	-	29	131	193	-	-	-	26	L1	6	-	-	-
Ronalane Bridge	63	7.5	8.8	69	7.5	9.4	63	127	162	25	132	178	57	L1	4	61	5.3	53
A.S.W.Q.O.	6.5 - 8.5																	

	Total Hardness ($mg \cdot L^{-1}$)						Specific Conductance ($uS \cdot cm^{-1}$)						Total Dissolved Solids ($mg \cdot L^{-1}$)					
	1970-75			1976-80			1970-75			1976-80			1970-75			1976-80		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	23	150	182	22	154	187	40	281	376	33	303	373	26	163	199	22	164	271
Cochrane	63	155	208	42	162	196	70	295	350	41	301	406	45	168	191	35	167	234
Carseland	94	166	260	-	-	-	86	333	431	-	-	-	48	183	235	-	-	-
Bassano	29	172	241	-	-	-	29	357	515	-	-	-	26	202	292	-	-	-
Ronalane Bridge	59	163	218	45	176	233	63	357	444	71	367	503	57	200	246	40	201	262
A.S.W.Q.O.																		

A.S.W.Q.O. = Alberta Surface Water Quality Objectives
L = Less Than

TABLE 1 Bow River Water Quality Data Summary (Routine Variables)(Cont'd).

	Colour (TCU)						Total Organic Carbon ($mg \cdot L^{-1}$)						Total Inorganic Carbon ($mg \cdot L^{-1}$)					
	1970-75			1976-80			1970-75			1976-80			1970-75			1976-80		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	37	5	10	33	5	10	24	2	22	-	-	-	24	22	38	-	-	-
Cochrane	52	6	40	47	7	40	47	4	23	18	5	18	45	22	43	18	23	33
Carseland	57	10	70	-	-	-	39	6	28	-	-	-	35	24	33	-	-	-
Bassano	29	10	40	-	-	-	20	7	19	-	-	-	18	23	48	-	-	-
Ronalane Bridge	63	12	60	32	8	25	57	6	20	24	6	20	52	24	36	24	26	41
A.S.W.Q.O.																		

	Phenolic Material ($mg \cdot L^{-1}$)						Oil & Grease ($mg \cdot L^{-1}$)						Biochemical Oxygen Demand ($mg \cdot L^{-1}$)					
	1970-75			1976-80			1970-75			1976-80			1970-75			1976-80		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	-	-	-	20	0.001	0.003	-	-	-	-	-	-	-	-	-	-	-	-
Cochrane	12	0.003	0.010	13	0.001	0.002	19	1.3	2.9	-	-	-	19	1.0	1.8	14	1.2	4.7
Carseland	37	0.004	0.020	-	-	-	44	1.4	5.0	-	-	-	46	2.4	7.8	-	-	-
Bassano	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ronalane Bridge	8	0.010	0.040	43	0.002	0.014	-	-	-	-	-	-	-	-	-	13	2.3	5.5
A.S.W.Q.O.		0.005																

A.S.W.Q.O. = Alberta Surface Water Quality Objectives
L = Less Than

TABLE 1 Bow River Water Quality Data Summary (Routine Variables)(Cont'd).

	Bicarbonate ($mg \cdot L^{-1}$)						Carbonate ($mg \cdot L^{-1}$)						Sulfate ($mg \cdot L^{-1}$)					
	1970-75			1976-80			1970-75			1976-80			1970-75			1976-80		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	26	135	154	6	130	150	26	0	0	22	0	3	26	38	54	22	42	177
Cochrane	63	144	180	41	145	185	63	L1	6	33	2	7	65	35	68	41	34	55
Carseland	75	149	189	-	-	-	75	2	31	-	-	-	83	39	82	-	-	-
Bassano	26	161	235	-	-	-	26	L1	7	-	-	-	28	48	74	-	-	-
Ronalane Bridge	57	154	198	25	157	217	57	L1	5	61	4	44	61	49	63	45	49	70
A.S.W.Q.O.																		

	Chloride ($mg \cdot L^{-1}$)						Fluoride ($mg \cdot L^{-1}$)						Calcium ($mg \cdot L^{-1}$)					
	1970-75			1976-80			1970-75			1976-80			1970-75			1976-80		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	26	0.7	1.3	22	1.0	2.0	26	0.1	0.2	22	0.1	0.6	26	40	50	22	40	49
Cochrane	65	1.2	8.0	41	1.3	5.0	66	0.1	0.5	35	0.1	0.2	65	43	62	42	43	55
Carseland	97	4.4	14.0	-	-	-	45	0.2	0.3	-	-	-	93	44	59	-	-	-
Bassano	28	2.9	6.0	-	-	-	14	0.2	0.3	-	-	-	29	47	70	-	-	-
Ronalane Bridge	61	3.6	15.0	45	4.3	8.7	31	0.1	0.3	40	0.1	0.2	62	45	62	45	44	67
A.S.W.Q.O.		0.005																

A.S.W.Q.O. = Alberta Surface Water Quality Objectives
L = Less Than

TABLE 1 Bow River Water Quality Data Summary (Routine Variables)(Cont'd).

	Magnesium ($mg \cdot L^{-1}$)						Sodium ($mg \cdot L^{-1}$)						Potassium ($mg \cdot L^{-1}$)					
	1970-75			1976-80			1970-75			1976-80			1970-75			1976-80		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	26	12	14	22	13	-	26	1.0	1.6	22	1.2	1.9	26	0.4	0.8	22	0.4	0.6
Cochrane	67	12	21	41	13	17	69	1.6	7.0	41	2.1	6.1	64	0.5	3.6	41	0.6	3.7
Carseland	92	13	35	-	-	-	85	5.3	9.9	-	-	-	84	1.2	4.4	-	-	-
Bassano	29	13	18	-	-	-	29	7.4	15.5	-	-	-	28	1.2	3.0	-	-	-
Ronalane Bridge	58	12	19	45	16	20	60	9.6	18.5	45	10.5	25	62	1.5	4.3	45	1.5	3.4
A.S.W.Q.O.																		

	Silica ($mg \cdot L^{-1}$)						Turbidity (JTU)						Non-Filterable Residue ($mg \cdot L^{-1}$)					
	1970-75			1976-80			1970-75			1976-80			1970-75			1976-80		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	26	3.8	4.4	3	4.0	4.2	36	3	17	33	2	16	-	-	-	21	4	56
Cochrane	50	3.5	10.9	13	3.8	8.3	67	4	25	40	4	40	19	6	20	26	4	40
Carseland	52	2.7	5.8	-	-	-	98	12	300	-	-	-	23	34	293	-	-	-
Bassano	27	2.2	5.4	-	-	-	29	11	105	-	-	-	13	39	276	-	-	-
Ronalane Bridge	58	2.4	12.5	16	2.2	4.5	63	18	120	63	10	42	20	53	210	58	19	170
A.S.W.Q.O.		0.005																

A.S.W.Q.O. = Alberta Surface Water Quality Objectives
L = Less Than

increased cultivation and lower annual rainfall. Summer evaporation and winter ice formation also act as concentrating mechanisms. Downstream of Calgary salt concentrations increase primarily as a function of industrial, municipal and irrigation return flow discharges to the river (Hamilton, Bodie and Schonekess 1982).

Even though salt concentrations increased downstream of Calgary, mean and maximum values remain well within the A.S.W.Q.O., and there are no appreciable differences in major ion chemistry between the early and late seventies.

The quantity of suspended particulate material in the water is measured by non-filterable residue (NFR) tests. This material includes clay, silt and sand particles, and some suspended organic matter. Average NFR values increased from above Canmore to the Ronalane Bridge, with the greatest increase occurring in the Calgary vicinity. Natural geologic and topographic transition from the foothills to the prairie region account for much of this increase because of factors such as increased soil erosion. Tributary streams, such as the Sheep and Highwood rivers, which flow through prairie agricultural areas, at times contribute significant quantities of suspended particulates to the Bow River. Anthropogenic sources are discussed in the effluent and loadings section (5.0).

The ability of a river to transport suspended particulate materials is related directly to stream discharge levels. The Bow River's NFR was greatest during June and early July when flows are highest, and lowest during fall and winter. Average NFR values at the

Ronalane Bridge from 1976 to 1980 were less than those of 1970 to 1975. This may be caused by the series of low flow years during the late 1970's.

Colour, a relative measure of light absorbance, is low overall with some increase in the reaches below Calgary. Average values were generally less than the level at which visual detection of colour is possible (McNeely et al. 1979).

Concentrations of total inorganic carbon showed no variation with distance downstream. However, concentrations of total organic carbon increased slightly. This increase was caused mainly by Calgary discharges, particularly treated sewage effluents, and by biological activity in the river.

Historically, phenolic compounds have been a problem in the Bow River downstream of Calgary. At very high concentrations they can be toxic to fish; at low levels they can cause fish tainting and taste problems in chlorinated public water supplies. As a consequence the A.S.W.Q.O. is set very low. Sources of phenol include industries, municipal wastes and decaying aquatic plants and algae. In the late and mid 1960's trout from downstream of Calgary often had an objectionable taste which was attributed to refinery discharges (Krishnaswami and Kupchanko 1969). The 1970 to 1975 data for the Bow River indicated relatively high levels as compared to the A.S.W.Q.O. Average phenolic concentrations at the Ronalane Bridge were lower for the latter half of the decade, probably because of decreased loadings to the river. Phenolic loadings are discussed in Section 5.3.

4.2 METALS

During the 1970's monitoring for 22 metals in the Bow River water was undertaken on a routine basis. Of these, only nine were measured in water samples at concentrations above current analytical limits of detection. Although all the data are presented in Table 2, discussion is restricted to those metals with obvious trends. The data have been examined for technique and detection limit variations which occurred over the ten-year period.

Aluminum concentrations increased considerably downstream of Calgary, yet remained within the normal surface water range of less than 1.0 $mg \cdot L^{-1}$ (McNeely et al. 1979). There are no surface water guidelines for aluminum since it is a significant threat to public health. Anthropogenic inputs at Calgary appear to explain the elevated concentrations in the lower reach and are discussed in Section 5.3. Aluminum concentrations measured at Ronalane Bridge were lower during the 1976 to 1980 interval as compared to the early half of the decade.

Boron and strontium similarly increased in concentration downstream. At all sites average boron concentrations remained low. Strontium is considered to be of no public health or aesthetic concern in its non-radioactive form. The observed trend for both boron and strontium can be attributed to erosion and dissolution from naturally occurring sedimentary materials.

Iron levels increased consistently between sites with a major increase apparent below Calgary. Average concentrations at Carseland and Ronalane Bridge exceeded the A.S.W.Q.O. High iron concentrations

TABLE 2 Bow River Water Quality Data Summary (Metals).

	Aluminum (EXT)						Arsenic (DIS)						Antimony (EXT)					
	1970-75			1976-80			1970-75			1976-80			1970-75			1976-80		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	-	-	-	-	-	-	-	-	-	20	L0.001	-	-	-	-	-	-	-
Cochrane	21	0.136	0.500	9	0.077	0.470	12	0.007	0.020	18	L0.001	-	14	L0.500	-	-	-	-
Carseland	10	0.409	2.500	-	-	-	6	L0.005	-	-	-	-	5	L0.500	-	-	-	-
Bassano	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ronalane Bridge	16	0.260	1.100	14	0.131	0.400	5	0.005	0.006	23	0.001	0.002	5	L0.500	-	-	-	-
A.S.W.Q.O.								0.010										

	Barium (EXT)						Boron (DIS)						Cadmium (EXT)					
	1970-75			1976-80			1970-75			1976-80			1970-75			1976-80		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	-	-	-	20	L0.050	-	-	-	-	20	0.023	0.035	-	-	-	20	L0.001	-
Cochrane	22	L0.100	-	7	0.063	0.100	8	0.034	60	7	0.029	0.070	12	L0.001	-	20	L0.001	-
Carseland	11	0.109	0.200	-	-	-	6	0.048	80	-	-	-	8	0.001	2	-	-	-
Bassano	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ronalane Bridge	16	L0.100	0.100	12	0.057	0.080	10	0.044	90	13	0.037	0.090	13	0.002	9	25	L0.001	-
A.S.W.Q.O.		1.000						0.500						0.010				

A.S.W.Q.O. = Alberta Surface Water Quality Objectives
L = Less Than
TOT = Total, DIS = Dissolved, EXT = Extractable
All values in $mg \cdot L^{-1}$

TABLE 2 Bow River Water Quality Data Summary (Metals)(Cont'd).

	Chromium (EXT)						Cobalt (EXT)						Copper (EXT)					
	1970-75			1976-80			1970-75			1976-80			1970-75			1976-80		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	-	-	-	-	-	-	-	-	-	20	L0.002	-	-	-	-	19	0.001	0.003
Cochrane	22	L0.010	-	9	L0.015		12	0.002	0.013	22	0.002	0.003	21	0.001	0.003	9	0.002	0.005
Carseland	11	L0.010	-	-	-	-	8	0.004	0.012	-	-	-	11	0.020	0.007	-	-	-
Bassano	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ronalane Bridge	16	L0.010	-	14	L0.015	-	12	0.002	0.003	27	0.002	0.003	16	0.003	0.012	13	0.001	0.002
A.S.W.Q.O.		0.050												0.020				

	Iron (DIS)						Iron (EXT)						Lead (EXT)					
	1970-75			1976-80			1970-75			1976-80			1970-75			1976-80		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	-	-	-	-	-	-	-	-	-	20	0.078	0.320	-	-	-	20	L0.004	-
Cochrane	33	0.018	0.080	-	-	-	20	0.103	0.560	9	0.167	0.990	23	0.001	0.004	20	0.004	0.009
Carseland	14	0.023	0.120	-	-	-	11	0.435	2.600	-	-	-	11	0.002	0.008	-	-	-
Bassano	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ronalane Bridge	18	0.075	1.010	-	-	-	16	0.453	2.300	14	0.334	1.100	16	0.002	0.006	25	0.005	0.022
A.S.W.Q.O.		1.000						0.300						0.050				

A.S.W.Q.O. = Alberta Surface Water Quality Objectives
L = Less Than
TOT = Total, DIS = Dissolved, EXT = Extractable
All values in $mg \cdot L^{-1}$

TABLE 2 Bow River Water Quality Data Summary (Metals)(Cont'd).

	Lithium (EXT)						Manganese (EXT)						Mercury (EXT)					
	1970-75			1976-80			1970-75			1976-80			1970-75			1976-80		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	-	-	-	-	-	-	-	-	-	20	0.010	0.019	-	-	-	13	L0.02	-
Cochrane	18	L.005	-	9	L.005	-	4	0.016	0.035	20	0.011	0.035	8	-	-	13	L0.02	-
Carseland	7	0.006	0.009	-	-	-	13	0.025	0.130	-	-	-	6	L0.05	-	-	-	-
Bassano	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ronalane Bridge	7	L0.005	-	8	0.007	0.011	16	0.028	0.100	25	0.033	0.290	10	L.0.05	-	17	L0.02	-
A.S.W.Q.O.								0.050						0.10				

	Molybdenum (EXT)						Nickel (EXT)						Selenium (DIS)					
	1970-75			1976-80			1970-75			1976-80			1970-75			1976-80		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	L.001	-
Cochrane	22	L0.050	-	20	L0.001	-	12	0.003	0.010	22	0.002	0.005	-	-	-	9	0.001	0.005
Carseland	11	L0.050	-	-	-	-	8	0.004	0.012	-	-	-	-	-	-	-	-	-
Bassano																		
Ronalane Bridge	15	L0.050	-	21	L0.001	-	13	0.004	0.008	27	0.004	0.019	6	L0.001	-	14	L0.001	-
A.S.W.Q.O.														0.010				

A.S.W.Q.O. = Alberta Surface Water Quality Objectives
L = Less Than
TOT = Total, DIS = Dissolved, EXT = Extractable
All values in $mg \cdot L^{-1}$ except Mercury in $ug \cdot L^{-1}$

TABLE 2 Bow River Water Quality Data Summary (Metals)(Cont'd).

	Silver (EXT)						Strontium (EXT)						Thallium (EXT)					
	1970-75			1976-80			1970-75			1976-80			1970-75			1976-80		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cochrane	20	L0.010	-	15	0.002	0.004	22	0.150	0.200	9	0.217	0.340	6	L0.100	-	-	-	-
Carseland	9	L0.010	-	-	-	-	10	0.197	0.350	-	-	-	3	L0.100	-	-	-	-
Bassano	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ronalane Bridge	10	L0.010	-	14	0.003	0.010	16	0.192	0.250	14	0.236	0.450	2	L0.100	-	-	-	-
A.S.W.Q.O.		0.050																

	Vanadium (EXT)						Zinc (DIS)						Zinc (EXT)					
	1970-75			1976-80			1970-75			1976-80			1970-75			1976-80		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	-	-	-	20	L0.001	-	-	-	-	-	-	-	-	-	-	-	-	-
Cochrane	18	L0.050	-	9	L0.001	-	37	0.004	0.032	-	-	-	19	0.003	0.016	9	0.002	0.004
Carseland	7	L0.050	-	-	-	-	11	0.004	0.010	-	-	-	9	0.004	0.008	-	-	-
Bassano																		
Ronalane Bridge	7	L0.050	-	13	L0.001	-	14	0.002	0.004	-	-	-	15	0.004	0.010	14	0.002	0.007
A.S.W.Q.O.														0.050				

A.S.W.Q.O. = Alberta Surface Water Quality Objectives
L = Less Than
TOT = Total, DIS = Dissolved, EXT = Extractable
All values in $mg \cdot L^{-1}$

in domestic water supplies can discolour clothes, plumbing fixtures, and encrust pipes. Iron concentrations increased naturally along the Bow River watercourse because of weathering of bedrock material, and input of groundwater which has naturally high concentrations. The considerable increase below Calgary is accentuated by man-made inputs.

Like iron, manganese concentrations in the Bow River are highest at Ronalane Bridge. Average concentrations do not exceed the guideline concentration of 0.05 $mg \cdot L^{-1}$; however, maximum values do. As for iron, the objectives have an aesthetic and economic basis. Manganese may impart taste, as well as stain fabric and porcelain at quite low concentrations. Manganese is derived naturally from soils, river sediments and sedimentary rocks. A potential seasonal source of manganese in the Bow River downstream of Calgary is decaying aquatic plant and algal populations. These populations develop between Calgary and Bassano during summer months, then die and decay during fall and winter.

Lead, nickel and zinc were detected in the system but only at trace levels. Between sites, means were very similar; however, maximum concentrations tended to be greatest at downstream sites. Average and maximum concentrations were well below the A.S.W.Q.O. The relation between these results and defined discharges to the river at Calgary is discussed in the effluent quality and loadings section (5.0).

A study by Ongley and Blachford (1982) investigated nutrient, metal and organochlorine residues on the suspended solids and in the aquatic plants of the Bow River.

They were able to define river course and seasonal trends for certain metals that are not discernible from the routine water quality data reviewed here. They detected elevated lead, copper, cadmium, chromium and nickel concentrations adhered to the suspended particulates downstream of Calgary during late summer and fall. The magnitude of the enrichment is small enough that during high flow periods naturally occurring background levels mask their detection. The elevated levels below Calgary approached upstream concentrations at a point above the Bassano Reservoir.

Enhanced concentrations of certain metals were also evident immediately downstream of the Bassano Dam and are thought to be derived from the reservoir sediments themselves. Accumulation of certain metals in the aquatic plants downstream of Calgary was also evident. However, trends were not as defined as were those for the sediments.

4.3 TRACE ORGANICS

During the 1970's the Bow River was monitored for a total of 23 organic compounds including selected pesticides, herbicides and polychlorinated biphenyls. Of those, only five were detectable in water samples, and only two were observed regularly (Table 3).

Amongst the pesticides, the organochlorine compounds are the most resistant to degradation and, therefore, most persistent in the environment. Of the various organochlorine insecticides monitored in the Bow River, only alpha- and gamma-BHC were detected. Gamma-BHC, an insecticide commonly known as lindane, was measured on rare occasions at Ronalane Bridge. The maximum observed concentration was 0.004 $\mu g \cdot L^{-1}$. Alpha-BHC was commonly found throughout the Bow River, with average concentrations increasing from above Canmore to Ronalane Bridge (maximum 0.010 $\mu g \cdot L^{-1}$). Unlike lindane, it has no insecticidal characteristics and is present only as an impurity in certain pesticide formulations (Gummer 1979). Prior to 1976 a pesticide of mixed BHC isomers that contained 60% to 70% alpha was marketed. Lindane is the only BHC isomer currently marketed, and it contains only 1% alpha as impurity. Gummer (1979), in his prairie-wide review of pesticides, noted widespread presence of alpha-BHC even in remote watersheds. He concluded that the presence of alpha-BHC in pristine waters must be caused by volatilization, atmospheric transport and redeposition. This hypothesis might explain the presence of alpha-BHC in the Bow River immediately below Banff National Park.

Of all the herbicides, only 2,4-D was found frequently in the Bow River, at very low concentrations while 2,4-DP was found rarely, also at very low concentrations. Of the chlorophenoxy acid herbicides, 2,4-D and MCPA account for 90% of the total herbicides used in western Canada (Gummer 1979). The maximum concentration

TABLE 3 Bow River Water Quality Data Summary (Trace Organics).

	P, P - DDT						P, P - DDD						P, P - DDE					
	1970-75			1976-79			1970-75			1976-79			1970-75			1976-79		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	8	L.D.	-	21	L.D.	-	8	L.D.	-	21	L.D.	-	8	L.D.	-	21	L.D.	-
Cochrane	7	L.D.	-	9	L.D.	-	7	L.D.	-	9	L.D.	-	7	L.D.	-	9	L.D.	-
Carseland	8	L.D.	-	-	-	-	8	L.D.	-	-	-	-	8	L.D.	-	-	-	-
Bassano	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ronalane Bridge	-	-	-	9	L.D.	-	-	-	-	7	L.D.	-	-	L.D.	-	7	L.D.	-

	P, P - Methoxychlor						Heptachlor						Heptachlor Epoxide					
	1970-75			1976-79			1970-75			1976-79			1970 75			1976-79		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	8	L.D.	-	21	L.D.	-	8	L.D.	-	21	L.D.	-	8	L.D.	-	21	L.D.	-
Cochrane	7	L.D.	-	9	L.D.	-	7	L.D.	-	9	L.D.	-	7	L.D.	-	9	L.D.	-
Carseland	8	L.D.	-	-	-	-	8	L.D.	-	-	-	-	8	L.D.	-	-	-	-
Bassano																		
Ronalane Bridge	-	-	-	9	L.D.	-	-	-	-	7	L.D.	-	-	L.D.	-	7	L.D.	-

All data in $ug \cdot L^{-1}$
$1.0\ ug \cdot L^{-1} = 0.001\ mg \cdot L^{-1}$
L.D. = Less than detectable

TABLE 3 Bow River Water Quality Data Summary (Trace Organics)(Cont'd)

	Alpha-Endo-Sulfhan						Beta-Endo-Sulfhan						Alpha-Chlordane					
	1970-75			1976-79			1970-75			1976-79			1970-75			1976-79		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	8	L.D.	-	21	L.D.	-	8	L.D.	-	21	L.D.	-	-	-	-	21	L.D.	-
Cochrane	7	L.D.	-	9	L.D.	-	7	L.D.	-	9	L.D.	-	-	-	-	9	L.D.	-
Carseland	8	L.D.	-	-	-	-	8	L.D.	-	-	-	-	-	-	-	-	-	-
Bassano	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ronalane Bridge	-	-	-	7	L.D.	-	-	-	-	7	L.D.	-	-	-	-	7	L.D.	-

	Gamma-Chlordane						Gamma-BHC (Lindane)						Alpha-BHC					
	1970-75			1976-79			1970-75			1976-79			1970-75			1976-79		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	-	-	-	21	L.D.	-	8	L.D.	-	21	L.D.	-	-	-	-	21	0.002	0.005
Cochrane	-	-	-	9	L.D.	-	7	L.D.	-	9	L.D.	-	-	-	-	9	0.003	0.006
Carseland	-	-	-	-	-	-	8	L.D.	-	-	-	-	-	-	-	-	-	-
Bassano	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ronalane Bridge	-	-	-	7	L.D.	-	3	L.D.	-	13	L0.001	0.004	-	-	-	13	L0.006	0.010

All data in $ug \cdot L^{-1}$
1.0 $ug \cdot L^{-1}$ = 0.001 $mg \cdot L^{-1}$
L.D. = Less than detectable
L = Less than.

TABLE 3 Bow River Water Quality Data Summary (Trace Organics)(Cont'd)

	Aldrin						Endrin						Dieldrin					
	1970-75			1976-79			1970-75			1976-79			1970-75			1976-79		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	8	L.D.	-	21	L.D.	-	-	-	-	21	L.D.	-	8	L.D.	-	21	L.D.	-
Cochrane	7	L.D.	-	9	L.D.	-	-	-	-	9	L.D.	-	7	L.D.	-	9	L.D.	-
Carseland	8	L.D.	-	-	-	-	-	-	-	-	-	-	8	L.D.	-	-	-	-
Bassano	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ronalane Bridge	-	-	-	7	L.D.	-	-	-	-	7	L.D.	-	-	-	-	7	L.D.	-

	Aroclor 1254						Aroclor 1248						Aroclor 1260					
	1970-75			1976-79			1970-75			1976-79			1970-75			1976-79		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	6	L.D.	-	21	L.D.	-	6	L.D.	-	21	L.D.	-	6	L.D.	-	21	L.D.	-
Cochrane	3	L.D.	-	9	L.D.	-	3	L.D.	-	9	L.D.	-	2	L.D.	-	9	L.D.	-
Carseland	5	L.D.	-	-	-	-	5	L.D.	-	-	-	-	4	L.D.	-	-	-	-
Bassano	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ronalane Bridge	7	L.D.	-	13	L.D.	-	8	L0.027	0.075	13	L.D.	-	8	L.D.	-	13	L.D.	-

All data in $ug \cdot L^{-1}$
1.0 $ug \cdot L^{-1}$ = 0.001 $mg \cdot L^{-1}$
L.D. = Less than detectable
L = Less than.

TABLE 3 Bow River Water Quality Data Summary (Trace Organics)(Cont'd)

	2, 4 - D						2, 4, 5 - T						MCPA					
	1970-75			1976-79			1970-75			1976-79			1970-75			1976-79		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	8	L.D.	-	21	0.0066	0.0320	8	L.D.	-	21	L.D.	-	8	L.D.	-	21	L.D.	-
Cochrane	3	L0.006	0.009	-	-	-	3	L.D.	-				-	-	-			
Carseland	7	L0.019	0.031	-	-	-	7	L.D.	-	-	-	-	5	L.D.	-	-	-	-
Bassano	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ronalane Bridge	9	0.032	0.095	15	0.0694	0.6000	9	L.D.	-	15	L.D.	-	9	L.D.	-	15	L.D.	-

	2, 4 - DB						2, 4 - DP					
	1970-75			1976-79			1970-75			1976-79		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Above Canmore	8	L.D.	-	21	L.D.	-	8	L.D.	-	21	L.D.	-
Cochrane	2	L.D.	-				2	L.D.	-			
Carseland	6	L.D.	-	-	-	-	6	0.004	0.007	-	-	-
Bassano	-	-	-	-	-	-	-	-	-	-	-	-
Ronalane Bridge	9	L.D.	-	15	L.D.	-	9	L.D.	-	15	L.D.	-

All data in $ug \cdot L^{-1}$
1.0 $ug \cdot L^{-1}$ = 0.001 $mg \cdot L^{-1}$
L.D. = Less than detectable
L = Less than.

of 2,4-D observed was 0.6 $\mu g \cdot L^{-1}$ during May 1978, consistent with a period of maximum usage. Average concentrations of 2,4-D increased with distance downstream, as well as with time. For instance, the average 2,4-D concentration at Ronalane Bridge was 0.0316 $\mu g \cdot L^{-1}$ for the interval 1970 to 1975 as compared to 0.0694 $\mu g \cdot L^{-1}$ for the period 1976 to 1979. A concentration of 1.0 $\mu g \cdot L^{-1}$ has been proposed as the level at which aquatic biological communities are affected (Gummer 1979).

Potential sources of 2,4-D to the Bow River would include agricultural drainage, urban runoff and municipal effluents. Although 2,4-D in Bow River irrigation return flows has not been monitored, it has been found in return flow waters in Saskatchewan (Cessna and Grover 1982). It has also been detected in Calgary urban runoff (Schonekess 1981). The marginal use of 2,4-DP relative to 2,4-D may account for its low frequency of detection (Gummer 1979).

Aroclor 1248 is a polychlorinated biphenyl (PCB) compound which was detected only at Ronalane Bridge on one occasion at a very low concentration. A review of the specific data for Aroclor 1248 at that site indicates that the only sample found to contain this compound was the first one collected when analysis for this parameter began in 1973. No Aroclor 1248 was detected after that first occurrence in spite of improvements in analytical techniques. This would suggest, therefore, that the initial detection which occurred in 1973 was more a function of analytical technique development than PCB presence in the Bow River. In the past Aroclors were most commonly

used as a component of electrical transformer oil. At present the use of PCB's is restricted, and, as old transformers are phased out, their probability of observation in the environment should decrease.

Many organic residues tend to disappear rapidly from the water phase through adsorption to sedimentary material or bio-uptake and accumulation. Ongley and Blachford (1982) were able to detect residues of specific organochlorine compounds on the suspended material of the lower Bow River which were not detectable in corresponding water samples. These include 1-3-5, 1-2-4 and 1-2-3 chlorobenzenes, alpha- and beta-BHC, alpha-chlordane, dieldrin and its metabolites, and PCB compounds. However, even on the sedimentary material, residue concentrations were only at, or very near, the limits of detection. As indicated previously, the use of compounds containing PCB's is restricted. Therefore, it is anticipated that with decreasing usage, residual PCB's in sedimentary material will not increase appreciably.

4.4 NUTRIENTS

Growths of nuisance filamentous algae and macrophytes have been a major problem in the Bow River in recent years (Exner 1977). If physical conditions are adequate, excess growth of algae and plants in surface waters is regulated by plant nutrient levels, in particular phosphorus and nitrogen. A limnological study of the South Saskatchewan River Basin (SSRBLS) was initiated in 1979 to investigate the relationship between nutrients and aquatic primary production throughout the basin. Two reports resulting from the study (Cross,

Hamilton, Charlton, 1986 and Charlton, Hamilton, Cross 1986) include data on nutrient sources, seasonal and spatial trends in nutrients, and the relationship between nutrients and plant growth for the entire South Saskatchewan River Basin. Only a brief summary of nutrient concentrations in the Bow River over the SSRBLS interval is presented and discussed here (Table 4).

Phosphorus is most often considered the nutrient controlling aquatic plant growth. Data for three forms of phosphorus are presented in Table 4. Soluble reactive phosphorus is composed mainly of orthophosphate, the major dissolved inorganic form. Soluble phosphorus includes dissolved inorganic and organic forms, while total phosphorus includes the soluble and particulate fractions. The relative biological importance of each form is addressed by the SSRBLS.

Upstream of Calgary total phosphorus concentrations were consistently low, whereas downstream of the city they increased to well above the A.S.W.Q.O. (0.05 $mg \cdot L^{-1}$). Sources of phosphorus in the Calgary vicinity are discussed in Section 5.2. Highest concentrations of all three forms was observed immediately below Calgary (Stier's Ranch) during winter months, with a marginal decrease further downstream. Average summer concentrations immediately below Calgary were lower than winter levels because of biological uptake and greater dilution by enhanced streamflow. Summer concentrations of soluble and soluble reactive phosphorus decreased substantially with distance downstream of Calgary, because of uptake by the aquatic plant and algal communities which developed in this reach. Consequently, the total phosphorus concentration at Ronalane Bridge for the interval 1979 to 1982 approached the A.S.W.Q.O.

TABLE 4 Bow River Water Quality Data Summary (Nitrogen and Phosphorus) 1979 - 1982

	Total Phosphorus						Soluble Phosphorus						Soluble Reactive Phosphorus					
	Winter			Summer			Winter			Summer			Winter			Summer		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Below Bearspaw	19	0.007	0.018	22	0.008	0.017	19	0.004	0.011	22	0.004	0.009	19	L0.003	-	22	L0.003	-
Stier's Ranch	15	0.328	0.580	10	0.132	0.260	15	0.267	0.370	11	0.106	0.220	15	0.244	0.350	11	0.073	0.160
Carseland	19	0.259	0.420	20	0.111	0.160	19	0.225	0.270	20	0.085	0.130	19	0.214	0.270	21	0.063	0.111
Bassano	20	0.243	0.450	23	0.093	0.160	20	0.201	0.270	24	0.066	0.150	20	0.189	0.270	24	0.052	0.120
Bow City	19	0.208	0.280	12	0.049	0.150	19	0.186	0.250	12	0.119	0.029	19	0.170	0.230	12	0.009	0.026
Ronalane Bridge	21	0.187	0.280	19	0.051	0.170	21	0.160	0.210	21	0.025	0.040	20	0.141	0.200	21	0.011	0.032
A.S.W.Q.O.		0.050																

	Total Nitrogen						Nitrate + Nitrite						Ammonia					
	Winter			Summer			Winter			Summer			Winter			Summer		
	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max	n	$\bar{x}$	max
Below Bearspaw	13	0.17	0.37	18	0.14	0.23	19	0.08	0.16	21	0.03	0.06	19	L0.1	-	22	L0.1	-
Stier's Ranch	8	2.19	3.90	10	1.14	1.82	15	0.64	1.70	11	0.80	1.20	13	1.3	2.8	10	0.2	0.5
Carseland	11	1.93	2.44	16	0.90	1.29	19	1.01	1.60	20	0.66	1.00	18	0.9	2.4	21	0.1	0.3
Bassano	11	1.82	2.76	19	0.60	0.88	20	1.10	1.60	25	0.33	0.68	18	0.8	2.4	25	0.1	0.6
Bow City	11	1.86	2.76	11	0.40	0.69	19	1.20	1.70	12	0.16	0.41	19	0.7	1.3	12	L.1	-
Ronalane Bridge	12	1.75	2.88	17	0.42	0.67	21	1.20	1.60	19	0.09	0.40	21	0.6	1.4	21	L.1	-
A.S.W.Q.O.		1.00																

A.S.W.Q.O. = Alberta Surface Water Quality Objectives
Winter = 01/12 to 31/03 Summer = 16/06 to 15/09 All values in $mg \cdot L^{-1}$)

Phosphorus concentration in drinking water is of no public health concern. It has a secondary impact on water supplies by causing proliferation of aquatic plants which, upon decay, can produce taste and odour problems. Nuisance weed growth also impairs operation of water diversion and withdrawal structures, and can have an impact on fisheries through oxygen stress and habitat impairment (Exner 1977). High nutrient levels in waters diverted for irrigation can also stimulate weed growth in canals and reservoirs. Because of the aquatic weed problem in the Bow River and its relationship to phosphorus derived from Calgary municipal effluents, advanced phosphorus removal was implemented during 1982 at both Calgary sewage treatment plants.

Like phosphorus, nitrogen concentrations in the Bow River increased from the sampling locations above Calgary to those below. Inorganic nitrogen forms include ammonia, nitrite and nitrate. In a surface waterbody with adequate oxygen, ammonia is converted to nitrate through nitrification. Nitrite is formed as an intermediate compound; however, it is very unstable and is rapidly transformed to nitrate. Because of the instability of nitrite, the results reported as nitrate plus nitrite in Table 4 represented nitrate almost entirely. Total nitrogen is a measure of all inorganic plus organic forms of nitrogen.

Winter total nitrogen concentrations downstream of Calgary were high, with little difference in average concentration between sites (2.19 to 1.75 $mg \cdot L^{-1}$). Of the inorganic forms, ammonia, the major form discharged in treated sewage and industrial effluents, was found in greatest concentration at Stier's Ranch. Average con-

centrations then decreased progressively towards Ronalane Bridge. Winter nitrate plus nitrite concentrations showed an inverse pattern with river distance, reflecting the instream conversion of ammonia to nitrate.

The average summer total nitrogen level immediately below Calgary was less than the corresponding winter value. Similarly, the summer decrease in total nitrogen downstream was greater and more rapid than the winter attenuation. These seasonal differences were caused by a number of factors: greater effluent dilution by higher summer discharges; higher water temperatures; uptake of both ammonia and nitrate ions by aquatic primary producers; loss of ammonia to the atmosphere during the ice-free season. Degradation of any organic nitrogen input to the Bow River is more rapid during periods when water temperatures are high. Organic nitrogen is converted by bacterial processing to inorganic ions, which in turn can be taken up by aquatic plants.

The Bow River exceeded the A.S.W.Q.O. for total nitrogen at all sites below Calgary during winter months and from Calgary to near Carseland during summer months. There is no Alberta Surface Water Quality Objective for ammonia. However, high concentrations of un-ionized ammonia can be toxic to fish. Based upon the existing healthy trout populations in the Bow River below Calgary, ammonia toxicity is not currently a problem.

4.5 BACTERIOLOGICAL INDICATORS

The common pathogenic diseases transmitted through surface waters include dysentery, cholera, typhoid, gastroenteritis, infectious hepatitis and poliomyelitis. Sources of the organisms causing these illnesses are infected people and animals. As such, these organisms can be introduced into sewage from homes, hospitals and industrial operations (i.e., animal handling, slaughtering), as well as agricultural and urban runoff contaminated with animal wastes. Since direct monitoring of most pathogens in rivers or lakes is not feasible, indirect indicators of microbial safety are used. Fecal contamination of a water may suggest the presence of pathogenic organisms; however, detection of the indicator does not confirm that a pathogen is actually being transmitted (McNeely et al. 1979).

Members of the coliform group of bacteria are the most commonly used microbiological indicators. The total coliform test measures gram-negative, non-spore forming, rod-shaped bacteria which ferment lactose to produce gas within 48 hours at 35°C. The coliform group includes some genera which are prolific in the intestinal tracts of warm-blooded animals and some which are naturally occurring in soil and water. The fecal coliform test measures specific genera which are found in the intestinal tracts of warm-blooded animals and which ferment lactose to produce gas within 24 hours at 44.5°C.

Both total and fecal coliform limits are usually included in water quality objectives. Fecal coliform limits are considered the more significant as they preclude the detection of coliform bacteria

of non-fecal origin. In surface waters the objectives vary by use (Alberta Environment 1977). For waters to be treated for domestic supply or used for non-contact recreation, 90 percent of samples over a 30-day period should have less than 5000 total coliforms per 100 mL and less than 1000 fecal coliforms per 100 mL. Water for direct contact recreation or vegetable crop irrigation should have less than 1000 total coliforms per 100 mL and 200 fecal coliforms per 100 mL as geometric averages of at least five samples in 30 days. These numbers should not be exceeded in more than 20 percent of the samples, or exceed 2400 per 100 mL on any day.

Three sources of microbiological data for the Bow River are documented in this report. Table 5 presents results of the long-term, monthly monitoring stations at Cochrane, upstream of Calgary, and at Ronalane Bridge. Although these data do not comply with the objective requirement of five samples over a 30-day interval, they do indicate long-term average values. Mean and range values above Calgary were consistent with all surface water objectives, as were average indicator densities at Ronalane Bridge. However, the maximum count near the confluence of the Bow and Oldman rivers exceeded 15,000 total coliforms per 100 mL.

To define the river course pattern of microbial indicators along the Bow River, three one-day synoptic surveys of the river were conducted in the summer of 1980 and 1981 (Table 6). On each occasion objective concentrations for all uses were met, except for the reach extending from Calgary to a point between the confluence with the Highwood River and Cluny.

TABLE 5 Bow River Bacteriological Data at Monthly Monitoring Stations (1976-79) Millipore Filtration Technique (Colonies/100 mL).

	TOTAL COLIFORMS			FECAL COLIFORMS		
	n	$\bar{x}$	(Range)	n	$\bar{x}$	(Range)
Cochrane	25	33	(2-212)	25	8	(0-134)
Near Confluence	25	793	(7-15,100)	26	29	(L2-180)

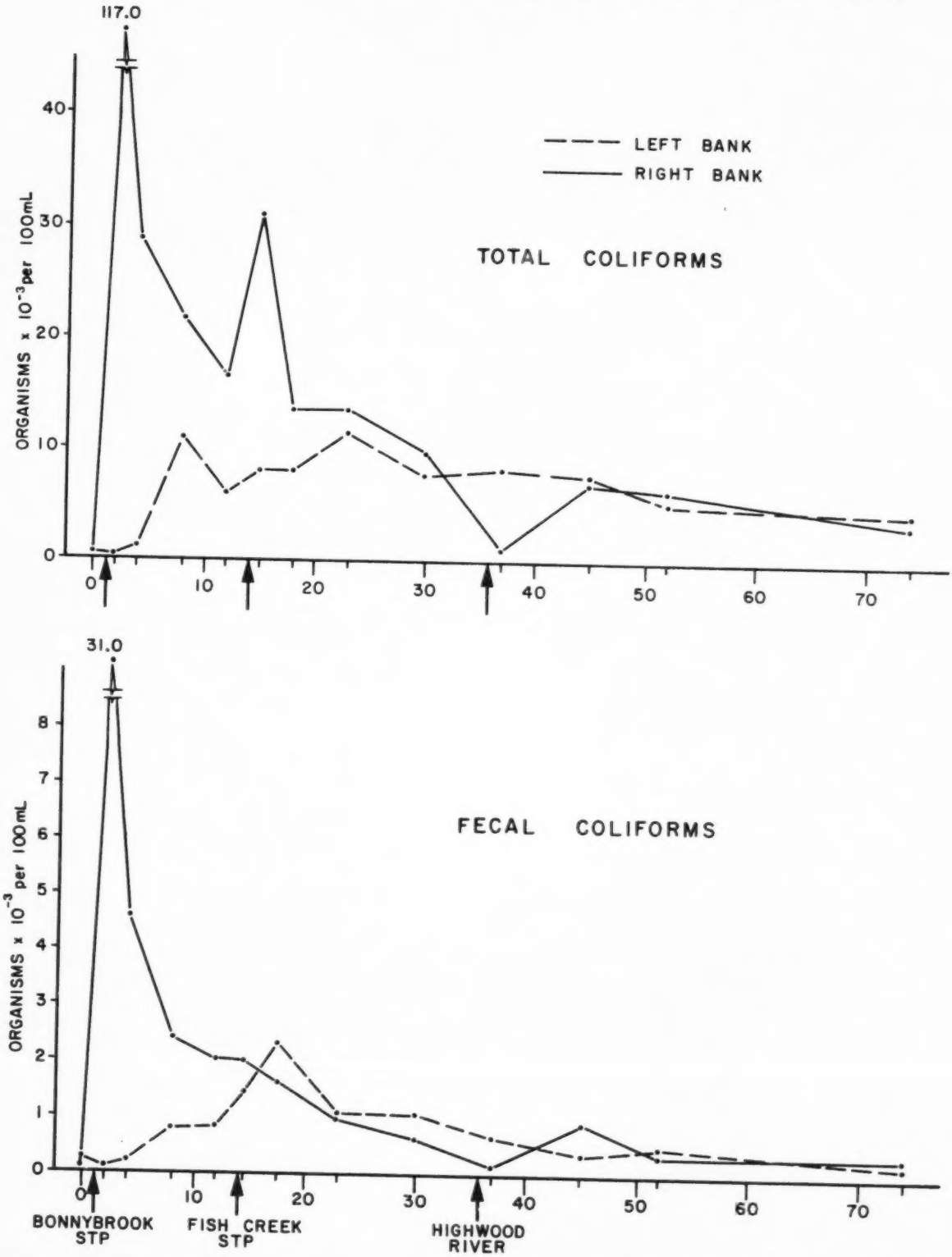
TABLE 6 Synoptic One-Day Surveys of Bacteriological Indicator Levels in the Bow River.

	14/07/80[1]		07/09/80[1]		31/08/81[2]	
	TC*	FC+	TC	FC	TC	FC
Below Brewster Creek	920	95	8	2	8	2
Near Morley	240	49	8	2	79	49
At Baker Sanitorium	11	4	-	-	13	5
Below Elbow River	170	79	130	33	79	79
Below Fish Creek	>2400	>2400	>2400	>2400	6,000	140
Below Highwood River	>2400	>2400	>2400	>2400	12,400	480
Near Cluny	33	13	14	4	920	220
Below Bassano Dam	14	2	110	110	540	70
Below Bow City	23	23	33	5	110	110
Below Ronalane Bridge	49	23	49	33	210	79
Near Mouth	113	11	22	5	240	130

* Total coliforms per 100 mL.
\+ Fecal coliforms per 100 mL.
1 Most probable number technique.
2 Millipore filtration technique.
> Greater Than

Alberta
ENVIRONMENT
Pollution Control Division
Water Quality Control Branch

FIG. 3 AVERAGE BACTERIOLOGICAL INDICATOR LEVELS IN BOW RIVER BELOW CALGARY (FALL 1981)



Detailed data from the fall of 1981 on the zone of high microbial indicator densities downstream of Calgary are portrayed in Figure 3. The graphs represent average total and fecal coliform results (n = 4) for 13 right and left bank sites spaced from immediately upstream of Calgary's Bonnybrook Sewage Treatment Plant (STP) effluent to a location downstream of Carseland. The Bonnybrook STP discharges to the right bank while the Fish Creek STP effluent enters midstream. The zone of mixing extends to a point approximately 25 kilometres downstream of the first Calgary sewage input. At that point the effluents are uniformly mixed from the right bank to the left bank and microbial densities are, therefore, similar from shore to shore. Coliform populations steadily declined from the very high levels immediately below Calgary to low densities near Carseland. These levels comply with the objective for surface waters suitable for domestic supply after treatment and secondary contact recreation. The more stringent direct contact recreational and vegetable crop irrigation guidelines are approached, but not met, by kilometre 74.

The zone of microbial die-off in a river system downstream of a point source discharge will vary depending upon numerous factors, including effluent volume and concentration, river discharge and temperature. However, the data indicate that during summer months the most pronounced bacteriological enrichment of the Bow River occurred in the reach from Calgary to Carseland with a return to near upstream indicator levels prior to Bassano Dam.

4.6 DISSOLVED OXYGEN

A detailed review of Bow River dissolved oxygen patterns is presented in the SSRBLS reports. River oxygen has been continuously monitored by WQCB field monitors established above and below Calgary. Dissolved oxygen levels remained high all along the Bow during winter, spring and fall periods. In the late 1970's nighttime summer oxygen concentrations below Calgary approached the minimum A.S.W.Q.O. of 5 $mg \cdot L^{-1}$. This occurred during years when nuisance weed and algal growth was particularly prolific, i.e., 1979. The diurnal depression is a result of the net respiratory demand of the aquatic plants over the nighttime period when they produce less oxygen than they consume.

5.0 EFFLUENT QUALITY AND RIVER LOADINGS

5.1 EFFLUENT TYPES AND DISCHARGE VOLUMES

Downstream of Banff National Park there were 18 point source discharges to the Bow River Basin (Table 7): nine industrial effluents and nine municipal sewage effluents. All but one industrial input, Madison Natural Gas Co. at Turner Valley, discharged directly to the Bow River (Figure 1). Two gas plants and one cement plant discharged to the Bow River upstream of Calgary. Licensed industrial effluents within the city included a refinery, two fertilizer plants and a gravel washing operation. Cominco Fertilizer at Carseland was the only industrial discharge to the Bow River downstream of Calgary.

Among municipal effluents, two towns discharged to the Highwood River and three to the Sheep River. Direct treated sewage discharges to the Bow River included Canmore and Cochrane upstream of Calgary and two plants within the city. Additional discharges to the Bow River, which had an impact on water quality, included Calgary's urban runoff and, in the lower reaches, return flow from the irrigation districts.

The total industrial, municipal and urban runoff discharge to the Bow River in 1980 was estimated at 229 x 10^6 m^3. This was a volume equal to 9% of the Bow River's 1980 total discharge at Calgary. In 1980, 7% of the input was from urban runoff, 33% from industries and 60% from municipal discharges. An effluent breakdown by source (Figure 4) indicates that industries on tributaries and industries upstream from Calgary have contributed only 13% of the

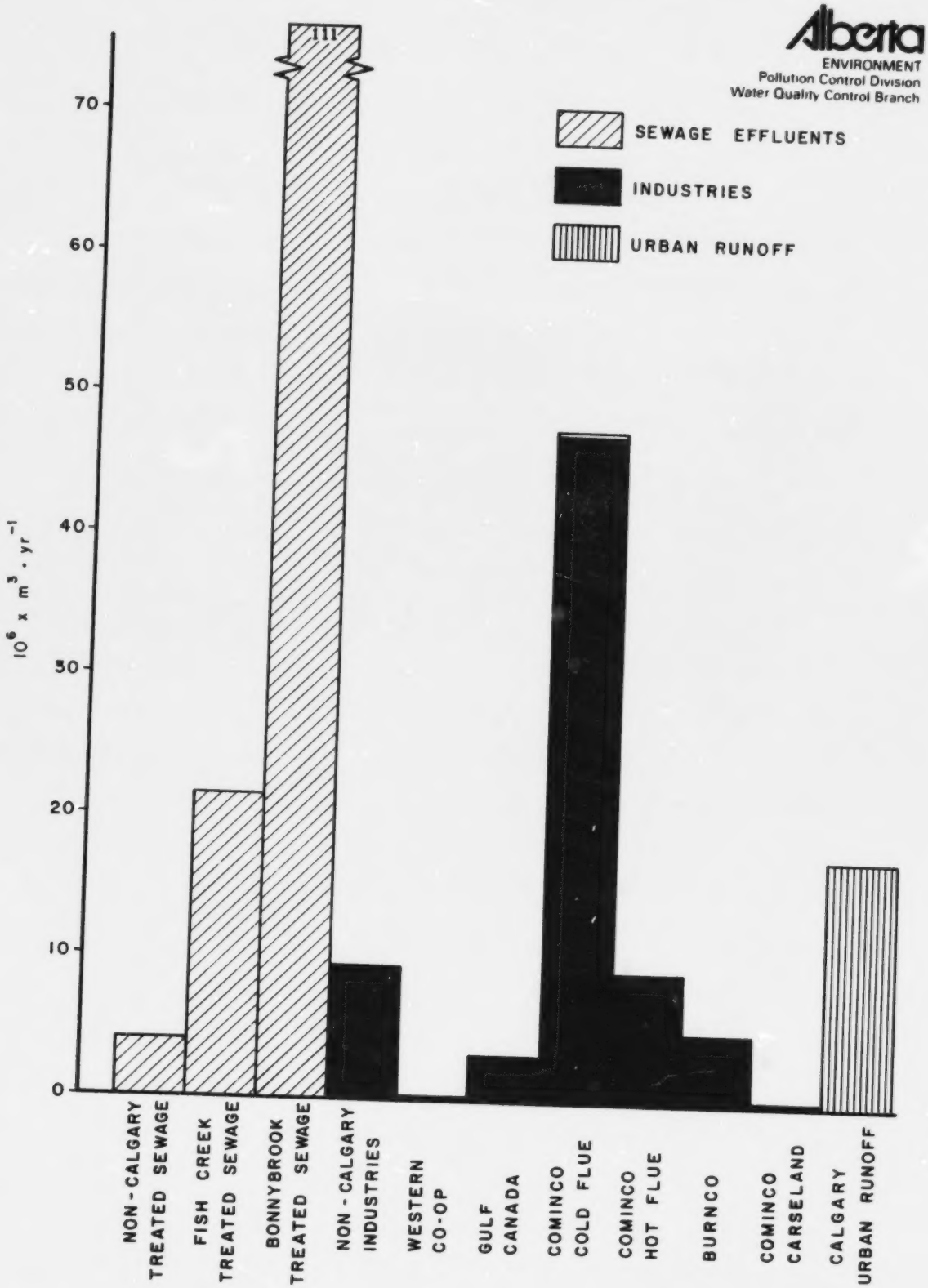
TABLE 7 Industrial and Municipal Discharges to Bow River Basin - 1980.

Industries	Receiving Stream
Madison Natural Gas Co. - Turner Valley	Sheep River
Canada Cement Lafarge - Exshaw	Bow River
Shell Canada - Jumping Pound	Bow via Jumping Pound Creek
Alberta Natural Gas - Cochrane	Bow River
Western Cooperatives Fertilizer - Calgary	Bow River
Gulf Canada Refinery - Calgary	Bow River
Cominco Fertilizer Ltd. - Calgary	Bow River
Burnco Products Ltd. - Calgary	Bow River
Cominco Fertilizer - Carseland*	Bow River

Sewage Treatment Plants	Receiving Stream
Longview	Highwood River
High River	Highwood River
Turner Valley	Sheep River
Black Diamond*	Sheep River
Okotoks	Sheep River
Canmore	Bow River
Cochrane	Bow River
Calgary - Bonnybrook Plant	Bow River
Calgary - Fish Creek Plant	Bow River

* intermittent discharge

FIG. 4. EFFLUENT DISCHARGES TO BOW RIVER BASIN - 1980



total industrial discharge, and non-Calgary sewage treatment facilities - a mere 3% of the total sewage input. Municipal and industrial discharges to the upper Bow River created localized zones of impact; however, their influence was so minimal that overall quality of the Bow River upstream of Calgary remained near its natural state (see Section 4.0). Similarly, discharges to the Sheep and Highwood rivers affected stream quality of immediately adjacent reaches. However, instream assimilation of wastes was such that the impact on Bow River water quality was minimal. Subsequent detailed analysis of effluent quality and net loadings is restricted to the Calgary area, since the sources there have the greatest impact on Bow River water quality.

Industrial discharge volumes remained relatively constant both annually and seasonally, while municipal effluents varied between years because of population fluctuations. None-the-less, the estimates used for both sources in Figure 4 are accurate. In contrast, the urban runoff estimated for the City of Calgary is an approximation based upon rainfall records and runoff coefficients since direct metering of storm drains was not possible. Urban runoff varied greatly by season and between years because of variable rainfall patterns. Consequently, the estimated urban runoff volume, and the river loadings calculated from it, are approximations with a high degree of error and variation. These estimates may be used for comparative purposes but not as absolute values.

5.2 EFFLUENT QUALITY

All effluent discharges discussed in this section are licensed by Standards and Approvals Division, Alberta Environment,

and undergo treatment prior to release. However, treatment technology is not able to remove all wastewater constituents and net loading for certain variables does occur. The effluent quality is compared to background river water quality.

Quality of the major effluents varied considerably by source (Table 8). Of the four fertilizer plant discharges to the Bow River, three were process effluents and one primarily cooling water. Cooling water discharge undergoes minimal water quality alteration since it is not chemically involved in production processes. Although Cominco's Calgary cold flume discharge rate was high, it was almost entirely cooling water, and its quality was similar to background river concentrations at the point of withdrawal.

General comparison of effluent quality to upstream Calgary river quality is valid, except for the Cominco's Calgary and Carseland effluents. These two plants withdrew water that was already altered by upstream inputs; therefore, the observed deviation between upstream river and effluent quality can be attributed only partially to plant input. Subsequent loadings analysis compensated for this factor.

Major variables affected by discharge from the fertilizer plants to the Bow River include some salts, as well as biochemical and chemical oxygen demand. Since all three plants produced nitrogen fertilizer, they also discharged nitrogen of various forms. Concentrations of phosphorus, silica, phenols, oil and grease, and organic carbon were greater in the fertilizer effluents relative to background river concentrations. Some discharge of aluminum, hexavalent chromium, iron, manganese, nickel and zinc also occurred.

TABLE 8 Quality of Major Discharges to Bow River in Calgary Vicinity(Cont'd).

	Gulf	Western CO-OP	Cominco Calgary (Cold Flume)	Cominco Calgary Hot Flume)	Burnco	Cominco Carseland	Calgary Sewage Effluents	Urban Runoff	Bow River @ Cochrane
Ammonia	0.117	30.144	2.353	3.811		0.193	15.99	0.740	
Nitrate +Nitrite	0.058	28.751	1.299	0.997	0.993	5.763	0.89*	1.740	
Aluminum	0.067	0.245	0.191	0.181			0.060*		0.077
Antimony	0.002	0.003	0.000	0.000					
Arsenic	0.003	0.012	0.013	0.002			0.001*		L.001
Berylium	0.001	0.091	0.001	0.001					
Cadmium	0.001	0.003	0.001	0.001			L.001		L.001
Chromium	0.004	1.200	0.003	0.004			0.048		L.015
Chromium^{+6}	0.006	0.542	0.005	0.005		0.005			
Cobalt	0.001	0.005	0.002	0.001			0.002*		0.002
Copper	0.002	0.017	0.009	0.015			0.021	0.033	0.002
Cyanide	0.002	0.062	0.001						
Iron	0.100	0.269	0.123	0.128	0.876	0..843	0.115	2.230*	0.167
Lead	0.004	0.009	0.003	0.007			0.018	0.458	0.004
Manganese	0.008	0.072	0.019	0.015			0.034*		0.011
Mercury	0.000	0.000	0.000	0.000					L.00002
Molybdenum	0.001	0.003	0.001	0.001					L.001
Nickel	0.001	0.016	0.004	0.003			0.008	0.009*	0.002
Selenium	0.011	0.002	0.000	0.000					0.001
Silver	0.001	0.001	0.001	0.001					0.002
Vanadium	0.002	0.009	0.002	0.002					L.001
Zinc	0.019	0.359	0.040	0.055			0.114	0.170	0.002

1 $uS \cdot cm^{-1}$
2 Jackson Turbidity Units
3 Threshold Odour Number
* Alberta Environment Data - All other STP Data supplied by City of Calgary
* Data from 68 St. Stormwater Pond - All other Urban Runoff Data from Nose Creek Drainage (Schonekess 1981)
L = Less Than
All values in $mg \cdot L^{-1}$ except as noted

TABLE 8 Quality of Major Discharges to Bow River in Calgary Vicinity

	Gulf	Western CO-OP	Cominco Calgary (Cold Flume)	Cominco Calgary Hot Flume)	Burnco	Cominco Carseland	Calgary Sewage Effluents	Urban Runoff	Bow River @ Cochrane
pH	7.9	8.0	7.7	7.6	7.8	7.0			7.9
Conductivity[1]	332	2851	383	412	358	1603			301
TDS	180	1900	206	211	190	1043	515*	233	167
Calcium	39.6	157.9	46.1	46.7	37.3	176.3	55.0*		43.0
Magnesium	12.6	58.2	14.1	14.5	15.0	67.3	23.0*		13.0
Sodium	10.6	322.8	10.3	13.5	10.3	52.3	71.0*		2.0
Potassium	0.7	10.2	1.8	1.7	2.4	9.5			0.6
Carbonate		22.5	17.5	11.0					2.0
Bicarbonate	143.6	130.5	134.6	156.1	160.6	48.3	290.0*		145.0
Sulfate	35.6	526.9	47.8	46.5	37.3	488.0	106.0*		34.0
Chloride	12.0	483.8	9.1	11.8	7.3	200.0	62.0*	7.0*	1.3
Fluoride	0.1	1.5	0.2	0.2	0.2	1.0			0.1
T. Alkalinity	118	121	132	130	132	39			123
T. Hardness	152	629	174	176	155	717			162
Turbidity[2]	7	14	8	6	116				4
NFR	16	28	12	19	166	13	14	1691	
Silica	3.3	12.7	3.1	3.1	5.0	131.0			3.8
Odour[3]	7.8	15.4	2.1	2.8		7.0			
BOD	7.8	13.2	10.4	10.8	4.8	3.0	16.0	16.9	1.2
COD	23.0	100.7	14.5	17.9	40.1	149.0	65.0*		
TOC	3.3	17.3	5.4	6.6	3.7	23.7		23.1	5.0
TIC	31.5	26.8	35.3	34.9	36.2	9.0			23.0
TC		45.7	40.0	41.6		32.6			28.0
Phenols	0.017	0.022	0.002	0.102		0.013	0.015	0.022*	0.001
Oil & Grease	2.058	3.278	2.721	2.523	0.489	0.800	1.000*		
Hydrocarbons	0.042		0.087	0.004					
Surfactants	0.130	4.129	0.283	0.324		2.000			
Total-P	0.047	5.151	0.434	0.497		3.183	3.540	1.522	0.006
Diss-P									
Ortho-P									
Total-N	0.493	31.632	2.879	5.881		2.053		6.830	

1 $uS \cdot cm^{-1}$
2 Jackson Turbidity Units
3 Threshold Odour Number
* Alberta Environment Data - All other STP Data supplied by City of Calgary
* Data from 68 St. Stormwater Pond - All other Urban Runoff Data from Nose Creek Drainage (Schonekess 1981)
L = Less Than
All values in $mg \cdot L^{-1}$ except as noted

The Gulf refinery discharged a process effluent which contained some oxygen demanding substances, total dissolved solids and nutrients. Some hydrocarbons, surfactants and phenolic compounds were also released. Selenium and zinc were the only metals in the Gulf effluent which deviated significantly from river background levels.

The major constituent of the Burnco effluent was NFR. Dissolution of some naturally occurring solutes, i.e., sodium and iron, resulted from the gravel washing process, and these substances were also evident in the effluent.

Calgary sewage plants discharged large quantities of phosphorus and nitrogen, the latter being primarily in the form of ammonia. These effluents also contained various amounts of total dissolved solids, oxygen demanding substances, and organic compounds such as phenolic compounds. Chromium, lead, manganese, nickel and zinc were the major metals identified in the Bonnybrook and Fish Creek discharges.

Although limited data were available for urban runoff, it did contain chloride, suspended solids, biochemical oxygen demand, organic carbon, phenolic compounds and nutrients. Iron, lead and zinc also occurred in elevated concentrations relative to river water.

5.3 EFFLUENT LOADINGS

The relative magnitude and importance of point source discharges to a river system cannot be discerned solely from evaluation of effluent concentration data. An effluent of very high concentration but low volume may have less impact on receiving water

quality than one of low concentration but high volume. Net annual loadings to the river provide this comparison, as they reflect mass added to the river.

Loading calculations were restricted to Calgary-area discharges because of their overriding importance within the Bow River Basin (Figure 5). Selection of variables for loadings analysis was based upon changes in downstream Calgary river water quality noted in Section 4.0 and availability of adequate data.

Sewage effluent was the major source for most constituents added to the Bow River at Calgary and, therefore, was the greatest factor contributing to altered water quality downstream of the city. Calgary sewage treatment plants were the major source of salts, biochemical oxygen demand, phosphorus and nitrogen. Input of phenolic substances was also dominated by sewage sources, with industries of secondary importance.

The major contributor of NFR in the Calgary area was urban runoff, which is extremely variable by season and between years. Urban runoff can have very high constituent concentrations, yet its overall loading for most variables is minor compared to the high volume but lower concentration associated with treated sewage.

Sewage effluent was the major contributor of chromium, copper and zinc while urban runoff was the major source of lead. Although not confirmed, the most likely source of the elevated aluminum concentrations observed below Calgary was aluminum hydroxide floc discharged from the water treatment plants. Some elevation of iron,

FIG. 5. NET ANNUAL LOADINGS (1980) TO BOW RIVER FROM INDUSTRIAL DISCHARGES, SEWAGE EFFLUENTS AND URBAN RUNOFF ORIGINATING IN CALGARY AREA ($kg \cdot yr^{-1}$)

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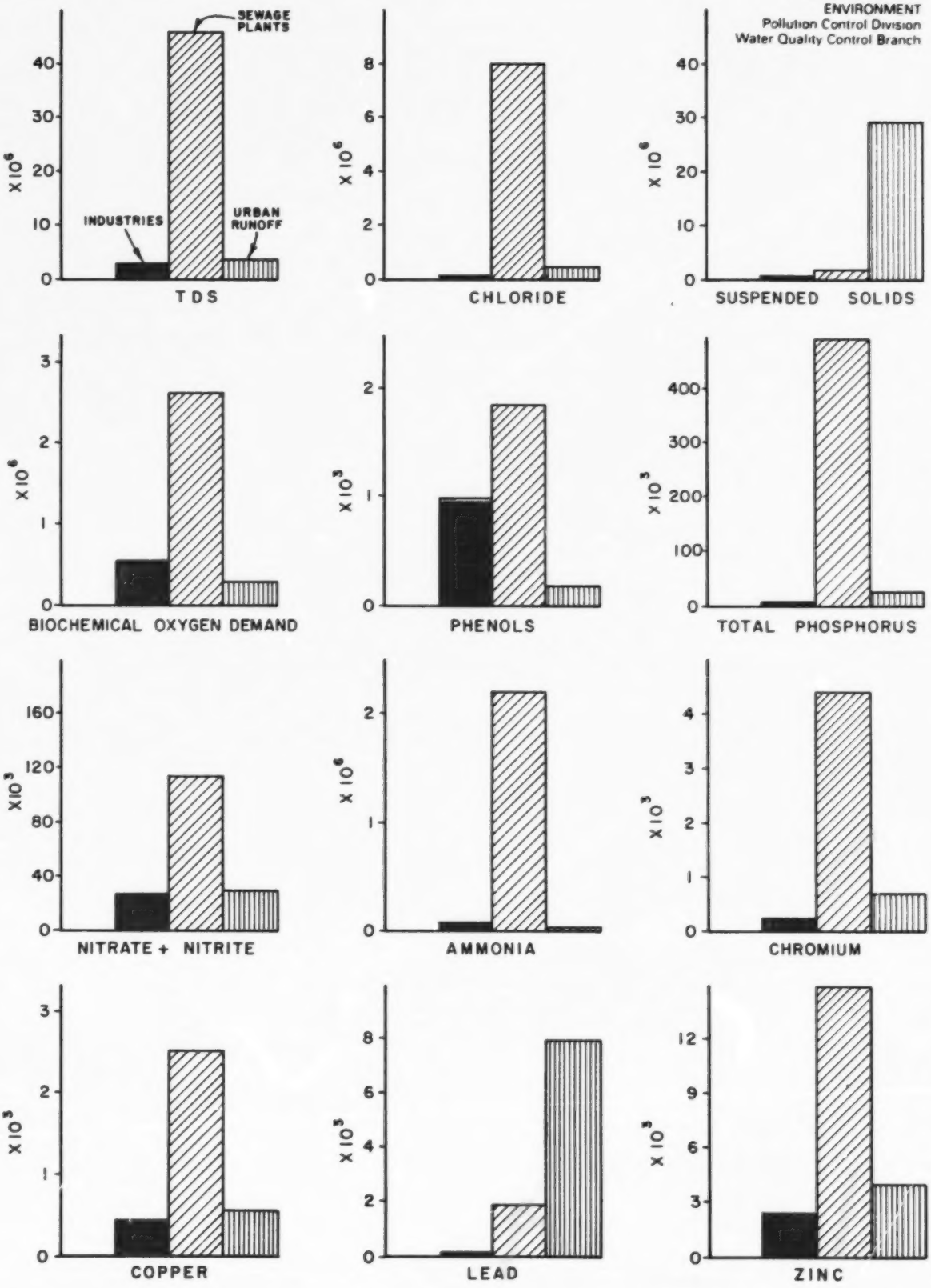

nickel, copper and cadmium also occurred downstream of the city, but the available data were insufficient to identify sources.

Loadings of bacteriological indicators could not be calculated. However, the river monitoring results indicated sewage as the major source. Industrial effluents characteristically have no significant microbial content. Urban runoff can exhibit high total and fecal coliform levels during storm events. The overall amount relative to the municipal discharges was minimal.

Snow dumps were an additional but extremely variable source of salts and metals to the Bow River. However, evaluation of 1980 data indicated that the relative annual input which could be attributed to this practice was minor.

The effect of loadings in the Calgary area on Bow River water quality was shown in the magnitude of observed changes in quality downstream of the city. The phosphorus, nitrogen and bacteriological inputs were very significant relative to all upstream sources. By comparison, the loading of metals from Calgary was of a lesser magnitude since elevation of down river concentrations was less dramatic. The 1980 annual loadings of chromium, copper, lead and zinc from Calgary account for 15% or less of the total load of these metals in the Bow River during the 1980 ice-free period (Ongley and Blachford 1982).

6.0 CONCLUSIONS

The water quality of the Bow River upstream of the City of Calgary was maintained generally near natural levels throughout the 1970's. Minor industrial and municipal discharges to this reach resulted in only localized alteration of quality.

Downstream of Calgary, Bow River quality was appreciably altered for certain constituents. In particular, phosphorus, nitrogen and microbiological ind'cator levels increased considerably. Other variables, such as phenolic compounds and total salts, increased to a lesser extent. These observed trends in river quality were related directly to the type and magnitude of discharges at Calgary. The sewage effluents from the two Calgary sewage treatment plants predominated for most variables, while industrial inputs and urban runoff were most often of minor significance.

Nutrient loadings to the lower Bow River from Calgary created nuisance aquatic weed and algal problems in the river, particularly during the series of very low river discharge years in the latter half of the 1970's. This growth, in turn, hindered use of the river for irrigation, recreation and fisheries.

Generally, metals and pesticides were maintained at trace levels throughout the river during the decade. Only one compound - the herbicide 2,4-D - appeared to have increased with time. Detection of certain metals and organochlorine compounds in the river sediments and biota occurred, but at very low levels.

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